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Comparative outcomes and cost-utility after surgical treatment of focal lumbar spinal stenosis compared with osteoarthritis of the hip or knee—part 1: long-term change in health-related quality of life

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Abstract

BACKGROUND CONTEXT: It is well accepted that total hip and knee arthroplasty (THA/TKA) for osteoarthritis (OA) is associated with reliable and sustained improvements in postoperative health-related quality of life (HRQoL). Although several studies have demonstrated comparable outcomes with THA/TKA after surgical intervention for lumbar spinal stenosis (LSS), the sustainability of the outcome after LSS surgery compared with THA/TKA remains uncertain.

PURPOSE: The primary purpose of this study is to assess whether improvements in HRQoL after surgical management of focal lumbar spinal stenosis (FLSS) with or without spondylolisthesis are sustainable over the long term compared with that of THA/TKA for OA.

STUDY DESIGN: Single-center, retrospective, longitudinal matched cohort study of prospectively collected outcomes, with a minimum of 5-year follow-up (FU).

PATIENT SAMPLE: Patients who had primary one- to two-level spinal decompression with or without instrumented fusion for FLSS and THA/TKA for primary OA.

OUTCOME MEASURES: Postoperative change from baseline to last FU in Short-Form 36 physical component summary (PCS) and mental component summary (MCS) scores among groups was used as the primary outcome measure.

METHODS: An age, sex-matched inception cohort of primary one- to two-level spinal decompression with or without instrumented fusion for FLSS (n=99) was compared with a cohort of primary THA (n=99) and TKA (n=99) for OA and followed for a minimum of 5 years. Linear regression was used for the primary analysis.

FU for the FLSS, THA, and TKA cohorts were n=20 (20.2%, same site [n=7] and adjacent segment [n=13]) requiring 27 operations, n=3 (3%, same site) requiring 5 operations, and n=8 (8.1%,

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The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

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same site) requiring 12 operations, respectively (p<.01). The average time to first revision was 56/65/43 months, respectively. Mean postoperative PCS (p<.0001) and MCS (p<.02) scores improved significantly and were durable for all groups at the last FU. The mean changes from baseline PCS/MCS scores to last FU were 8.5/6.4, 12.3/7.0, and 8.3/4.9 for FLSS, THA, and TKA, respectively. Adjusting for baseline age, sex, body mass index, PCS score, and MCS score, there was a strong trend in favor of greater sustained change in the PCS score of THA over FLSS (p=.07) and TKA (p=.08). No difference was noted for change in PCS score between FLSS and TKA (p=.95). No differences were noted for change in MCS score among all three cohorts (p>.1).

CONCLUSIONS: Significant improvements in HRQoL after surgical treatment of FLSS with or without spondylolisthesis and hip and knee OA are sustained for a mean of 7 to 8 years, with a minimum of 5-year FU. Despite a higher revision rate, patients undergoing surgery for FLSS can expect a comparable long-term average improvement in HRQoL from baseline compared with their peers undergoing TKA and to a lesser extent THA.

Keywords: Long term; Spinal stenosis; Osteoarthritis; Hip; Knee; Surgery; Health-related quality of life

Introduction

Musculoskeletal disorders such as low back pain and osteoarthritis (OA) are among the leading causes of years lived with disability and have a major impact on functional capacity [1,2]. Consistent with the increasing prevalence of these conditions within the aging population, the demand for surgical treatment of OA of the hip, knee, and spine has been on the rise [3–8]. As the global population continues to age, this trend has serious implications for the future use of health-care resources in these three common surgical populations [9].

Standard surgical treatment of end-stage symptomatic hip and knee OA consists of total hip and knee arthroplasty (THA/TKA), respectively; the surgical management of symptomatic OA of the spine (ie, lumbar spinal stenosis [LSS] with or without degenerative spondylolisthesis) are decompression and decompression with fusion [4]. Primary THA and TKA have proven to be the effective and durable treatments for hip and knee OA, in terms of pain relief, improved functional status, quality of life (QoL), and overall patient satisfaction [10–12]. Furthermore, primary THA and TKA have proven to be among the most cost-effective surgical interventions, both musculoskeletal and otherwise [13–15]. Over the past decade, there has been increasing recognition and awareness of the challenges posed by the scarcity of health-care resources against virtually unlimited health-care needs and increasingly expensive modes of treatment [9,16]. As a result, decision makers at all levels are under greater pressure to justify their resource allocation and priority-setting decisions. Specific to the surgical management of degenerative illnesses, issues of surgical wait time, budget impact, cost-effectiveness, and utilization are an ongoing focus of health policy [5–8,17–23]. Subsequently, societal demand combined with sustainable cost- and clinical effectiveness of THA and TKA have played a pivotal role in the general acceptance of these procedures by all stakeholders (patients, health-care providers, surgeons, payers, and government agencies) [24].

In contrast, until more recently, the data supporting the long-term cost- and clinical effectiveness of surgery for LSS are limited and inconsistent regarding durability [25–32]. Recent work from our group and others has demonstrated that surgical management of patient with focal lumbar spinal stenosis (FLSS) (one to two level) with or without degenerative lumbar spondylolisthesis (DLS) results in comparable improvement in health-related quality of life (HRQoL) compared with TKA at 2 years after surgery [32–37]. In addition, we have also demonstrated that from the perspective of the hospital, the estimated lifetime cost-utility of spinal surgery for the aforementioned LSS population is also comparable with both THA and TKA [38]. The current two-part study presents long-term clinical and cost-utility data from our previously published spine, hip, and knee cohorts [36,38]. The primary objective of part one, presented herein, was to assess whether improvement in HRQoL after surgical management of FLSS with or without DLS is sustainable over the long term compared with THA/TKA for OA.

Methods

Study design

This is a single-center, retrospective, longitudinal matched cohort study of prospectively collected outcomes, with a minimum of 5-year follow-up (FU).

Patient population

As described in Rampersaud et al. [36], the inception cohort was determined after treatment and independently (by research individuals not involved in patient care) selected from databases containing prospectively collected outcome measurements of consecutive patients who received THA and TKA for OA and decompression with or without fusion for LSS at our institution (academic tertiary care hospital) over a 4-year period from January 2000 to December

2003. Before receiving a surgical assessment, each patient had undergone at least 6 months of conservative care. Conservative care entailed typical care as per the referring physician (analgesia, formal and informal exercise, activity modification, and assistive devices where applicable). At the time of the index surgery, the typical wait time for referral to surgical consultation in the study populations was over 1 year and the average surgical wait time (time for decision to proceed with surgery to surgery) was 6 to 12 months for all three cohorts.

Inclusion criteria for LSS were intermittent neurogenic claudication resulting from one- or two-level spinal stenosis (ie, FLSS), with or without DLS. Exclusion criteria for this group included other causes of spinal stenosis (congenital, posttraumatic, and degenerative scoliosis); multilevel surgery (more than two levels); previous surgeries at the symptomatic (previous discectomy was accepted) or adjacent level; or multilevel coronal and sagittal plane deformity. One- and two-level LSS were chosen a priori to compare with total joint arthroplasty (TJA) as they represent the most common cases of surgery for LSS and have surgical parameters similar to those of TJA (morbidity and hospital stay). Patients in the THA and TKA groups had mechanical pain resulting from primary OA of the hip or knee. Exclusion criteria included secondary causes of OA (posttraumatic), inflammation, and previous surgery other than knee arthroscopy.

All patients represent a pragmatic cohort, where the decision to offer and accept surgery was an elective decision between the patient and the usual practice of the treating surgeon. All consecutive patients who underwent surgery for the generic LSS diagnosis (n=220) during the study period were assessed for the inclusion and exclusion criteria; 99 patients met the previously noted inclusion criteria and were independently matched to a larger cohort of hip (n=248) and knee (n=260) OA patients fitting the inclusion criteria. Nine patients (all without DLS) in whom complete FU data were obtained subsequent to inception cohort analysis and thus not reported in 2008 publication are included in this analysis (did not have 2-year data but had long-term data). The cohorts were matched in a blinded (blinded to outcome data) manner according to age (within 2 years), sex, and date of surgery. Matching to within 1 month of surgical date was performed to eliminate any possible effects from the potential variance of health-care delivery or other unknown system confounders. If multiple matches were found, a best-fit (age and date of surgery) principle was used.

Surgery

Surgical management of FLSS entailed a decompression alone or decompression with fusion. A midline anatomy-preserving decompression was used for patients receiving decompression alone. This was chosen for patients with leg-dominant symptoms (based on consensus between patient and surgeon that leg symptoms are greater and/or more functionally significant than axial back symptoms and the goal of surgery was to relieve the leg symptoms) relieved by postural change/rest, no or tolerable mechanical back pain, anatomy favorable to facet-sparing (ie, undercutting) decompression, and no obvious dynamic instability with or without static spondylolisthesis (up to Grade I). Patients who had greater than Grade I spondylolisthesis or dynamic instability demonstrated on supine to standing or flexion-extension imaging, who had facet anatomy that precluded adequate decompression, or who had concomitant mechanical back pain resulting from one- or two-level disease that was felt to be intolerable by the patient received decompression with instrumented fusion. Patients who underwent both decompression and fusion had a conventional open midline approach with complete laminectomy and segmental pedicle screw fixation with the use of local bone and iliac crest bone graft (in the majority).

For the hip and knee patients, an uncemented THA was performed using the Hardinge (lateral) approach and a cemented TKA using a medial parapatellar approach, respectively, was used in all patients.

Subsequent surgeries performed on the same site, for hip and knee OA, were considered as a revision. Contralateral or adjacent joint replacement was not included as a revision. Spine revision was defined as same site surgery and/or adjacent site surgery.

Data collection

Data included the following patient characteristics: age, sex, body mass index (BMI), and American Society of Anesthesiologists (ASA) physical status classification. The preoperative and postoperative (1- and 2-year) Medical Outcomes Study Short-Form 36 (SF-36) general health survey scores were assessed. As part of prospective registries and ongoing quality assurance initiatives, validated disease-specific (hip and knee OA Index of Western Ontario and McMaster Universities/LSS Oswestry Disability Index) and generic outcome (SF-36) measures have been prospectively collected within the division of orthopedic surgery since 1998 (TJA) and 2000 (spine). The SF-36 has been shown to be valid and responsive to a wide variety of medical diagnoses. Furthermore, it has shown appropriate responsiveness compared with disease-specific outcome measures for both degenerative spinal pathologies (Oswestry Disability Index) and hip and knee OA (OA Index of Western Ontario and McMaster Universities) [39–41].

Outcome measures

The postoperative change from baseline to last FU in SF-36 physical component summary (PCS) and mental component summary (MCS) scores among groups was used as the primary outcome measure. Because of the dramatic differences in resource needs and surgical intensity of decompression alone versus decompression and fusion, we also performed a subgroup analysis regarding change from baseline PCS score for FLSS patients undergoing decompression alone or decompression and fusion compared with H-OA and K-OA.

Institutional ethics approval

The study was approved by the Institutional Research Ethics Board (#04-0283-BE).

Statistical analysis

Statistical analysis was performed by an independent biostatistician. SAS 9.3 (SAS Institute Inc., Cary, NC, USA) statistical package was used to perform the analyses. Summary statistics to assess the baseline comparability of the groups with respect to demographics were used. Unadjusted comparisons among groups were performed using one-way analysis of variance (for continuous variables) and *t* test or Pearson chi-square test (for categorical variables).

Univariate analyses were conducted to identify factors that were different among cohorts or significantly related to outcomes. Age, gender, BMI (different distribution among cohorts at last FU), and baseline PCS and MCS scores were all entered into simple linear regression models to adjust for the relationship of outcomes comparing spinal surgery with arthroplasty and subgroup analyses of specific procedures. Follow-up time was not shown to be associated with any of the outcomes in the univariate tests ($p=.78$ for PCS score change and $p=.65$ for MCS score change).

Results

Patient baseline characteristics

Baseline patient demographics are presented in Table 1. At baseline, the three groups (FLSS/H-OA/K-OA) were equally matched with respect to mean age, sex, BMI, and ASA physical status ($p>.1$). Within the FLSS group, 62 patients had decompression alone (n=30, one level; n=32, two level) and 28 had decompression and instrumented fusions (n=12, one level; n=16, two level). Thirty-eight patients within the FLSS group had a concomitant degenerative spondylolisthesis (n=21, decompression alone; n=17, decompression and fusion). For the FLSS cohort, there were no differences in subgroups with respect to baseline patient demographics and SF-36 PCS/MCS scores for those who had decompression (D) alone, those who had decompression and fusion (DF), and those with and without DLS ($p>.1$ for all groups).

The mean FUs in months were 80.5 ± 16.04, 94.6 ± 16.62, and 80.6 ± 16.84 for the FLSS, H-OA, and K-OA cohorts, respectively. The range of FU was 5 to 10 years for all three cohorts. The number of remaining participants in each cohort at the last FU with a minimum of 5 years for the FLSS, H-OA, and K-OA cohorts were 78 (79%), 91 (92%), and 84 (85%), respectively. Within the 21 lost to FU in the FLSS cohort, 7 were deceased and 2 with confirmed terminal diseases; of

Table 1
Matched inception cohort baseline demographics and PCS and MCS scores

Baseline information	FLSS	H-OA	K-OA
Age in y (range)	64.2 (42–84)	63.0 (40–84)	64.6 (43–83)
Sex (female/male)	59/40	59/40	59/40
BMI (range)	26.7 (16.3–54.2)	24.0 (18.3–40.1)	27.6 (18.2–56.1)
ASA physical status (median)	2	2	2
Baseline PCS score (SD)	31.41 (7.92)	29.73 (7.05)	31.41 (7.89)
Baseline MCS score (SD)	43.10 (11.3)	44.99 (9.90)	45.62 (9.70)

ASA, American Society of Anesthesiologists; BMI, body mass index; FLSS, focal lumbar spinal stenosis; H-OA, hip osteoarthritis; K-OA, knee osteoarthritis; PCS, physical component summary; MCS, mental component summary; SD, standard deviation.

Note: There was no statistical difference among groups ($p=.58$, analysis of variance).

the 8 lost to FU for the H-OA cohort, 3 were deceased; and of the 15 lost to FU for the K-OA cohort, 3 were deceased and 2 in long-term care facilities (Figure). The mean time in months at which patients were lost to FU was similar among groups (FLSS 38.1 ± 11.5, H-OA 31.5 ± 11.0, and K-OA 30.0 ± 10.9). Only two patients in each of the FLSS and H-OA cohorts were lost after the 5-year FU period. Compared with the baseline demographic and outcome data of the last FU cohorts, there was no difference in age (for H-OA and K-OA), sex, BMI, and baseline PCS or MCS score to those lost to FU within each cohort. In the FLSS cohort, the lost to FU group was significantly older than those followed (61+11.7 vs. 72+8.7 years for those lost to FU, $p<.001$).

Unadjusted univariate analysis of FU cohorts

Analysis of the baseline data of the patients with a minimum of 5-year FU demonstrated no difference in age at surgery ($p=.59$), baseline PCS ($p=.22$) or MCS ($p=.22$) scores, or male/female distribution ($p=.95$). The BMI for the FU cohorts, however, was significantly different among cohorts (28.4 ± 4.5, 29.8 ± 6.2, and 32.0 ± 6.6 for FLSS, H-OA, and K-OA, respectively, $p<.001$). As demonstrated in Table 2, the mean postoperative PCS ($p<.0001$) and MCS ($p<.02$) scores improved significantly for all groups. For our primary outcome, there was no difference in the mean PCS score among cohorts at last FU ($p=.37$); however, the mean change in PCS score ($p=.03$) from baseline was significantly different in favor of the H-OA cohort. There was no significant difference in the mean ($p=.46$) or the mean change from baseline ($p=.18$) MCS score among cohorts.

Adjusted analysis

For our primary outcome, adjusting for baseline age, sex, BMI, PCS score, and MCS score, there was no

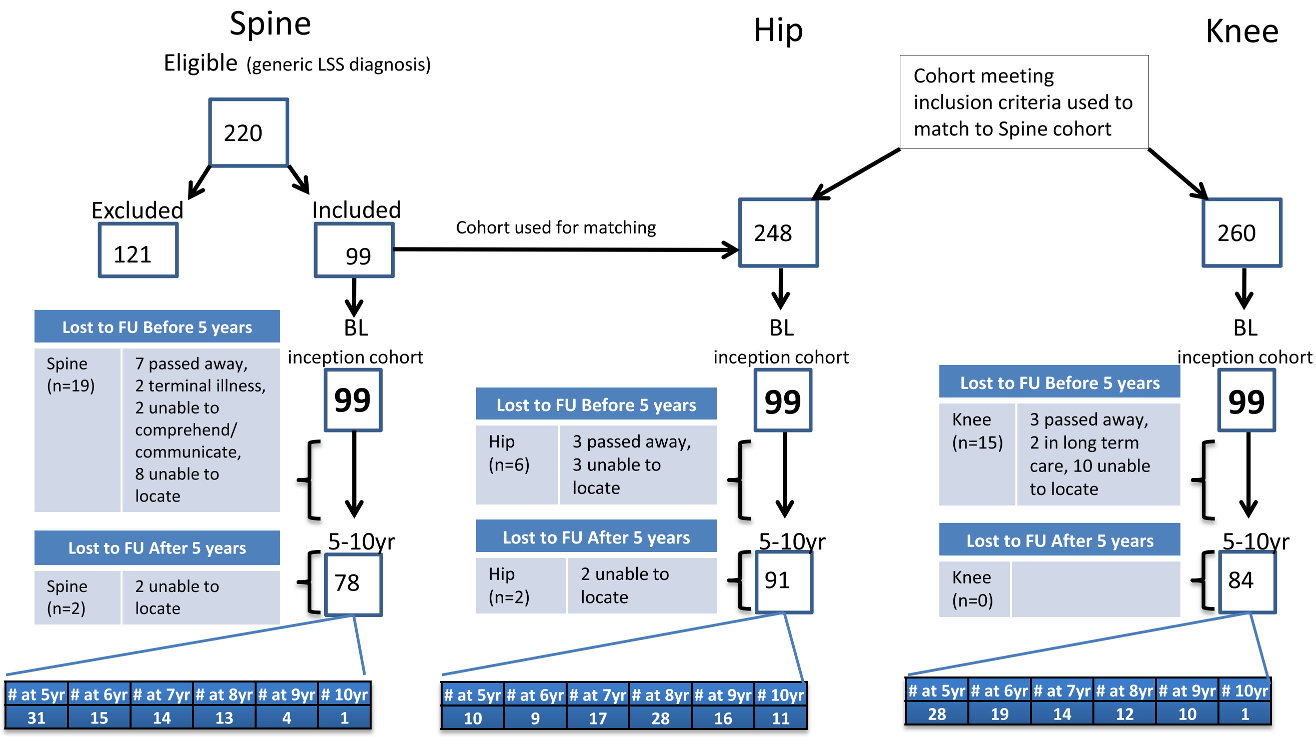

Figure. Number of patients followed up/lost, at each time point.

statistically significant difference in the change from baseline PCS score or MCS score to last FU among groups (Table 3). A trend for greater change was noted for the H-OA compared with both the FLSS (p=.07) and K-OA (p=.08) cohorts.

Adjusted subgroup analysis demonstrated almost identical findings for the decompression-alone cohort as those noted previously for the entire FLSS cohort (thus data not presented). For the smaller decompression and fusion cohort, the superior findings related to H-OA were no longer significant (Table 4).

Revision surgery

At the last FU, the current revision rate (for definitions, see "Methods" section) was significantly higher for the FLSS cohort and lowest for the H-OA cohort. The number of patients who have undergone revision, including those lost to FU, for spine, hip, and knee are n=20 (20.2%) requiring 27 operations, n=3 (3%) requiring 5 operations, and n=8 (8.1%) requiring 12 operations, respectively (p<.01). The average time to first revision was 56/65/43

Table 2
Mean PCS and MCS scores at 5- to 10-year FU

	5–10 y		
Variable	Mean (change from baseline)	SD	p Value*
PCS score			
FLSS (n=78)	39.93 (8.52)	10.37	<.0001
H-OA (n=91)	41.98 (12.25)	11.66	<.0001
K-OA (n=84)	39.74 (8.33)	11.86	<.0001
MCS score			
FLSS (n=78)	49.49 (6.39)	10.90	<.0001
H-OA (n=91)	51.97 (6.98)	11.00	<.0001
K-OA (n=84)	50.53 (4.91)	12.50	.01

FLSS, focal lumbar spinal stenosis; FU, follow-up; H-OA, hip osteoarthritis; K-OA, knee osteoarthritis; MCS, mental component summary; PCS, physical component summary; SD, standard deviation.

* p Values represent comparison from baseline within each cohort.

Table 3
Simple linear regression models: PCS/MCS score change from baseline for FLSS (decompression alone+decompression and fusion)/THA/TKA at 5- to 10-year FU

Variable	Reference	Coefficient	95% CI for coefficient	p Value
PCS score change from baseline to last FU				
H-OA	FLSS	3.37	−0.34 to 7.08	.07
K-OA	FLSS	0.12	−3.72 to 3.97	.95
H-OA	K-OA	3.25	−0.33 to 6.83	.08
MCS score change from baseline to last FU				
H-OA	FLSS	2.07	−1.87 to 6.01	.30
K-OA	FLSS	−0.85	−4.94 to 3.24	.68
H-OA	K-OA	2.92	−0.89 to 6.73	.13

CI, confidence interval; FLSS, focal lumbar spinal stenosis; FU, follow-up; H-OA, hip osteoarthritis; K-OA, knee osteoarthritis; MCS, mental component summary; PCS, physical component summary; SD, standard deviation; THA/TKA, total hip and knee arthroplasty.

Note: Adjusted for baseline age, sex, body mass index (BMI), PCS score, and MCS score. Baseline PCS score, sex, age, and BMI were significantly related to the outcome (p<.02).

Table 4
Simple linear regression models (subgroup analysis): PCS score change from baseline for FLSS decompression and fusion (DF), FLSS (DF)/THA/TKA at 5- to 10-year FU

Variable	Reference	Coefficient	95% CI for coefficient	p Value
PCS score change from baseline to 5- to 10-year FU				
H-OA	FLSS (DF)	2.61	−3.23 to 8.46	.38
K-OA	FLSS (DF)	−0.97	−6.92 to 4.98	.75

CI, confidence interval; FLSS, focal lumbar spinal stenosis; FU, follow-up; H-OA, hip osteoarthritis; K-OA, knee osteoarthritis; PCS, physical component summary; MCS, mental component summary; SD, standard deviation; THA/TKA, total hip and knee arthroplasty.

Note: Adjusted for baseline age, sex, body mass index, PCS score, and MCS score. All parameters were significantly related to the outcome ($p<.02$).

months, respectively. Subgroup revision rates for the FLSS cohort are shown in Table 5.

Discussion

The results of this study confirm the positive, significant, and sustained impact on HRQoL in patients electing to undergo surgical intervention for spine, knee, and hip OA on HRQoL. Furthermore, this study demonstrates that the improvement from baseline HRQoL for the surgical management of FLSS previously demonstrated at 2 years is sustainable beyond 5 years and comparable with that of TJA for H-OA and K-OA. However, the reoperation rate for the FLSS cohort is significantly higher than that of THA and TKA [36]. These results have far-reaching implications from a direct patient care and health policy perspective. It is estimated that over the next 30 to 40 years, the proportion of seniors in Canada, the United States, and in most global industrialized countries (those older than 60–65 years) will double [42–44]. In addition, Perruccio et al. [45] have noted an increasing prevalence of arthritis that was not explainable by the aging population alone. Perruccio et al. [45] estimated that by 2021, the prevalence of arthritis in Canada would be increased 21% to 26% compared with 17.6% in 2003. In the United States, several authors have noted similar concerns and have reported on the rapidly increasing rate of surgery for degenerative conditions of the spine and TJA [4–8,17,18,20,21]. The implications of our study on health system funding and human resource allocation are substantial if we are to accommodate the increasing demand in the surgical care of Musculoskeletal conditions, particularly OA of the spine, hip, and knee [9,19].

In Canada, wait times can result in significant delays in obtaining surgical consultation and management for elective disorders in certain specialities and subspecialties [33,46,47]. Wait times for obtaining surgical services for common procedures such as total joint replacement have been particularly publicized [19,48–51]. In 2003, the Canadian First Ministers' Accord on Health Care Renewal was struck and a commitment to achieve meaningful reductions in wait times in priority areas such as cancer, heart, diagnostic imaging, joint replacements, and sight restoration was publically made [50]. Since that time, significant, and often dramatic, improvements have been made in accessibility in these five top priority areas. Prioritization of hip and knee replacement was not only purely on the basis of patient demand but also from the consistent demonstration of comparative clinical effectiveness, durability, and cost-effectiveness of TJA [10]. In other words, hip and knee TJA has demonstrated significant health-care value [52].

The results of this study combined with the current growing higher quality literature for LSS suggest that similar arguments that have been made for THA/TKA can now be made for the surgical management of LSS. It is estimated that LSS causing neurogenic claudication affects about 20% of people older than 65 years and about half of that group suffer serious restrictions in their daily routines [53,54]. In a recent study by Battié et al. [54], the authors demonstrated that associated health burden of LSS on HRQoL was significant and is about the same or greater than diabetes, heart disease, arthritis, or stroke. Furthermore, LSS is the commonest reason to undergo spine surgery in patients older than 65 years [4,5,18]. Superior and sustained comparative cost- and clinical effectiveness for surgical management compared with conservative management at 2 and 4 years postoperatively for LSS with or without DLS have

Table 5
Revision surgery for the FLSS cohort

			Same site		Adjacent segment	
FLSS Subgroup	Primary	Revisions (number of surgeries)	D	DF	D	DF
LSS with DLS (n=38)	D (n=21)	3 (3) Mean time to revision 44.3 (m)	0	1 (1)	1 (1)	1 (1)
	DF (n=17)	7 (9) Mean time to revision 43.1 (m)	0	2 (2)	0	5 (7)*
LSS without DLS (n=61)	D (n=51)	7 (12) Mean time to revision 41.4 (m)	1 (1)	3 (4)	1 (1)	2 (6)
	DF (n=10)	3 (3) Mean time to revision 55.3 (m)	0	0	0	3 (3)

D, decompression; DF, decompression and fusion; DLS, degenerative lumbar spondylolisthesis; FLSS, focal lumbar spinal stenosis.
Note: Revisions=number of patients with (number of surgeries).
* One unrelated remote L1 fracture.

been recently demonstrated by the large multicenter Spine Patient Outcomes Research Trial studies confirming the finding of previous smaller studies [25–27,55,56]. The demonstration of comparable and sustainable improvement of HRQoL after the surgical management of FLSS compared with the benchmark set by TJA for OA enables patients, surgeons, and policy and decision makers to consider not only the comparative effectiveness within the spine literature but also two well accepted and familiar nonspine interventions commonly performed in the aging population. Our group has also demonstrated generalizability by affirming our 2-year results in a recent multicenter study [33]. The relatively consistent results achieved among hospital centers in our multicenter study suggest that unlike the surgical management of low back pain for degenerative disc disease, consistent surgical outcome for the management of FLSS is achievable on a national scale [57,58]. Furthermore, our early findings at 2 years postintervention are in line with several other similar studies that have been conducted in different countries [33–37]. The consistency across multiple studies affords a greater degree of confidence in our findings.

There are several notable strengths to this study. First, it still remains one of the first studies to provide direct comparison of four common surgical interventions in a growing population. Second, we used a validated patient-reported generic outcome measure (SF-36) that has shown adequate sensitivity across our study populations [39–41]. Third, the pragmatic nature of our matched inception cohort enables a greater degree of generalizability. Fourth, we have achieved an excellent response rate from all three cohorts at a minimum of 5-year (5–10 years) FU, ranging from 79% for the FLSS cohort and 92% for the H-OA cohort. Fifth, and most importantly, the long-term of minimum 5-year FU (mean of 7 years for FLSS and K-OA and 8 years for H-OA) enables a direct assessment of the relative clinical and surgical durability of these interventions. Although limited, the long-term literature for the surgical treatment of LSS is consistent with the findings of the current study. In 11 studies (6 prospective studies, 2 of which were randomized controlled trials) with a mean FU ranging from 5 to 13 years, outcomes and patient satisfaction were relatively maintained in the majority of patients (53–92%) [56,59–68]. The revision rates for the LSS population varied widely from 1% to 23%, with the majority reporting a revision rate of less than 10%. The revision rate in our FLSS cohort is certainly in the upper end of those reported and, however, is consistent with the rates reported by several prospective studies and one large administrative database study [26,27,62,63,69]. Furthermore, all same site (n=7 patients) and adjacent segment procedures (n=13 patients) were included in our revision rate, with the majority (65%) of revisions indicated for adjacent segment disease. The results of our H-OA and K-OA cohorts are consistent with the long-term clinical and surgical outcomes of TJA [70–77].

The limitations of this study are primarily methodological in nature and related to the retrospective selection of our consecutive FLSS inception cohort from prospective databases. The potential confounding effects of patient selection biases and difference in surgical technique cannot be accounted for but reinforces generalizability. Although the SF-36 allows for valid comparisons among different disease states or interventions, it nevertheless has a deficiency in orthopedic conditions, particularly in mental and social subcomponents, where it is less responsive to change and is subject to significant floor or ceiling effects [78]. This is possibly why there is significantly less difference in change for the MCS among our cohorts. Furthermore, determination of the PCS and MCS is dependent of some shared subscales and consequently is not independent. Another potential confounder that has been shown to impact the change in SF-36 after surgery is the presence or absence of medical or other MSK comorbidities [73,79]. Although surgical and anesthetic screening will have excluded patients with more severe cardiovascular or respiratory conditions, the effects of medical or psychosocial comorbidities common to these surgical populations were not controlled in this study. Furthermore, we did not collect specific data nor adjust for the likely development of new comorbidities or other joint dysfunction over the time duration of our study. Differential development of additional comorbidities among cohorts is likely and may influence the relative changes in SF-36 scores. However, controlling for other variables including age, sex, baseline BMI, ASA, and baseline SF-36 scores adjust for factors relevant to the patient and surgeon at the time of choosing surgical intervention. Furthermore, we also did not adjust for revision status; therefore, the negative impact of a higher revision rate for the FLSS cohort is reflected in the current data. Consequently, we feel that these data are valid from the perspective of the overall long-term HRQoL outcome regardless of future health events including revision surgery that may influence the HRQoL.

Another potential limitation of this study relates to biases and assumptions related to the comparison of different patient populations. First, our combination of spinal subdiagnoses (LSS with or without DLS) and surgical intervention (decompression alone or with instrumented fusion) from a policy perspective represents the common spectrum of LSS patients; thus, we felt it more relevant to assess the population as a whole. However, our spine cohort mixture (with or without DLS and decompression vs. decompression and fusion) is consistent with those presented in the aforementioned long-term studies. Consequently, we are confident that our spine cohort is representative of the typical patient undergoing surgery for FLSS. Second, although we are comparing relative change in outcomes from baseline among the spine, hip, and knee cohorts, outcomes may have been differentially impacted by possible differences in the degree of failure of nonoperative treatment among groups. However, because of the prolonged wait times for consultation and eventual surgical intervention during that period of time in our health-care system, further improvement with conservative care was less likely in the present study. Specifically, as demonstrated by other Canadian studies [46,49], hip, knee, and spine patients are more likely to deteriorate while waiting for elective surgery rather than improve. These patients represent individuals who have failed to gain any benefit from further conservative care and elected to endure a significant wait (6–12 months) to have surgery. Furthermore, to reduce surgical burden and manage wait-list, any available methods to optimize nonoperative treatment before and after the decision to proceed with surgery are typically pursued.

Conclusions

For patients failing prolonged conservative care, significant improvement in HRQoL after elective surgical treatment of FLSS (including those with and without degenerative spondylolisthesis) and hip and knee OA is sustained to a mean of 7 to 8 years with a minimum of 5-year FU. Despite a higher revision rate, patients undergoing surgery for FLSS can expect a comparable long-term average improvement in HRQoL from baseline compared with their peers undergoing TKA and to a lesser extent THA.

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References

[1] Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2013;380:2163–96.
[2] Reynolds DL, Chambers LW, Badley EM, et al. Physical disability among Canadians reporting musculoskeletal diseases. J Rheumatol 1992;19:1020–30.
[3] Agency for Healthcare Research and Quality. Healthcare cost and utilization project, HCUPnet. Available at: http://www.ahrg.gov/data/hcup/index.html. Accessed January 26, 2013.
[4] Deyo RA, Mirza SK, Martin BI, et al. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. JAMA 2010;303:1259–65.
[5] Deyo RA, Gray DT, Kreuter W, et al. United States trends in lumbar fusion surgery for degenerative conditions. Spine 2005;30:1441–5; discussion 1446–7.
[6] Kurtz S, Mowat F, Ong K, et al. Prevalence of primary and revision total hip and knee arthroplasty in the United States from 1990 through 2002. J Bone Joint Surg Am 2005;87:1487–97.
[7] Jain NB, Higgins LD, Ozumba D, et al. Trends in epidemiology of knee arthroplasty in the United States, 1990-2000. Arthritis Rheum 2005;52:3928–33.
[8] Mehrotra C, Remington PL, Naimi TS, et al. Trends in total knee replacement surgeries and implications for public health, 1990-2000. Public Health Rep 2005;120:278–82.
[9] Buckwalter JA, Heckman JD, Petrie DP, AOA. An AOA critical issue: aging of the North American population: new challenges for orthopaedics. J Bone Joint Surg Am 2003;85-A:748–58.
[10] Ethgen O, Bruyere O, Richy F, et al. Health-related quality of life in total hip and total knee arthroplasty. A qualitative and systematic review of the literature. J Bone Joint Surg Am 2004;86-A:963–74.
[11] Malchau H, Garellick G, Eisler T, et al. Presidential guest address: the Swedish Hip Registry: increasing the sensitivity by patient outcome data. Clin Orthop Relat Res 2005;441:19–29.
[12] Malchau H, Herberts P, Eisler T, et al. The Swedish total hip replacement register. J Bone Joint Surg Am 2002;84-A(2 Suppl):2–20.
[13] Laupacis A, Bourne R, Rorabeck C. Costs of elective total hip arthroplasty during the first year. J Arthroplasty 1994;9:315–21.
[14] Lavernia CJ, Guzman JF, Gachupin-Garcia A. Cost effectiveness and quality of life in knee arthroplasty. Clin Orthop Relat Res 1997;345:134–9.
[15] Chang RW, Pellisier JM, Hazen GB. A cost-effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. J Am Med Assoc 1996;275:858–65.
[16] Dobrow MJ, Goel V, Uphsur REG. Evidence-based health policy: context and utilisation. Soc Sci Med 2004;58:207–17.
[17] Cowan JA Jr, Dimick JB, Wainess R, et al. Changes in the utilization of spinal fusion in the United States. Neurosurgery 2006;59:15–20.
[18] Weinstein JN, Lurie JD, Olson PR, et al. United States' trends and regional variations in lumbar spine surgery: 1992-2003. Spine 2006;31:2707–14.
[19] Shipton D, Badley EM, Mahomed NN. Critical shortage of orthopaedic services in Ontario, Canada. J Bone Joint Surg Am 2003;85-A:1710–5.
[20] Lavernia C, Lee DJ, Hernandez VH. The increasing financial burden of knee revision surgery in the United States. Clin Orthop Relat Res 2006;446:221–6.
[21] Rasanen P, Ohman J, Sintonen H, et al. Cost-utility analysis of routine neurosurgical spinal surgery. J Neurosurg Spine 2006;5:204–9.
[22] Rivero-Arias O, Campbell H, Gray A, et al. Surgical stabilisation of the spine compared with a programme of intensive rehabilitation for the management of patients with chronic low back pain: cost utility analysis based on a randomised controlled trial. Br Med J 2005;330:1239–45.
[23] Neumann PJ, Rosen AB, Weinstein MC. Medicare and cost-effectiveness analysis. N Engl J Med 2005;353:1516–22.
[24] Canadian Orthopaedic Foundation. First Ministers' Health Accord 2004. Position Statement on First Ministers' Health Accord 2004–March 2005. Available at: http://www.canorth.org/en/docs/PositionsonPublicPolicy-HealthAccord2004.pdf. Accessed November 15, 2009.
[25] Tosteson ANA, Tosteson TD, Lurie JD, et al. Comparative effectiveness evidence for spinal stenosis, degenerative spondylolisthesis, and intervertebral disc herniation. Spine 2011;36:2061–8.
[26] Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical versus nonoperative treatment for lumbar spinal stenosis: four-year results of the Spine Patient Outcomes Research Trial. Spine 2010;35:1329–38.
[27] Weinstein JN, Lurie JD, Tosteson TD, et al. Surgical compared with nonoperative treatment for lumbar degenerative spondylolisthesis: four-year results in the Spine Patient Outcomes Research Trial (SPORT) randomized and observational cohorts. J Bone Joint Surg Am 2009;91:1295–304.
[28] Katz JN. Cost-effectiveness of spine surgery: the jury is out. Ann Intern Med 2008;149:901–3.
[29] Gibson JN, Waddell G. Surgery for degenerative lumbar spondylosis: updated Cochrane Review. Spine 2005;30:2312–20.
[30] Mardjetko SM, Connolly PJ, Shott S. Degenerative lumbar spondylolisthesis: a meta-analysis of literature 1970–1993. Spine 1994;19(20 Suppl):2256–65.
[31] Turner JA, Ersek M, Herron L, Deyo R. Surgery for lumbar spinal stenosis: attempted meta-analysis of literature1970-93. Spine 1992;17:1–8.

[32] Bono CM, Lee CK. The influence of subdiagnosis on radiographic and clinical outcomes after lumbar fusion for degenerative disc disorders: an analysis of the literature from two decades. Spine 2005;30:227–34.

[33] Rampersaud YR, Wai EK, Fisher CG, et al. Postoperative improvement in health-related quality of life: a national comparison of surgical treatment for focal (one- to two-level) lumbar spinal stenosis compared with total joint arthroplasty for osteoarthritis. Spine J 2011;11:1033–41.

[34] Mokhtar SA, McCombe PF, Williamson OD, et al. Health-related quality of life: a comparison of outcomes after lumbar fusion for degenerative spondylolisthesis with large joint replacement surgery and population norms. Spine J 2010;10:306–12.

[35] Hansson T, Hansson E, Malchau H. Utility of spine surgery: a comparison of common elective orthopaedic surgical procedures. Spine 2008;33:2819–30.

[36] Rampersaud YR, Ravi B, Lewis SJ, et al. Assessment of health-related quality of life after surgical treatment of focal symptomatic spinal stenosis compared with osteoarthritis of the hip or knee. Spine J 2008;8:296–304.

[37] Juul O, Sigmundsson FG, Ovesen O, et al. No difference in health-related quality of life in hip osteoarthritis compared to degenerative lumbar instability at pre- and 1-year postoperatively: a prospective study of 101 patients. Acta Orthop 2006;77:748–54.

[38] Tso P, Walker K, Mahomed N, et al. Comparison of lifetime incremental cost:utility ratios of surgery relative to failed medical management for the treatment of hip, knee and spine osteoarthritis modelled using 2-year postsurgical values. Can J Surg 2012;55:181–90.

[39] Salaffi F, Carotti M, Stancati A, Grassi W. Health-related quality of life in older adults with symptomatic hip and knee osteoarthritis: a comparison with matched healthy controls. Aging Clin Exp Res 2005;17:255–63.

[40] Marx RG, Jones EC, Atwan NC, et al. Measuring improvement following total hip and knee arthroplasty using patient-based measures of outcome. J Bone Joint Surg Am 2005;87:1999–2005.

[41] Walsh TL, Hanscom B, Lurie JD, Weinstein JN. Is a condition-specific instrument for patients with low back pain/leg symptoms really necessary? The responsiveness of the Oswestry Disability Index, MODEMS, and the SF-36. Spine 2003;28:607–15.

[42] Statistics Canada. Population projections: Canada, the provinces and territories. The Daily, 2010. Available at: www.statcan.gc.ca. Accessed December 22, 2010.

[43] US Census Bureau. An older and more diverse nation by midcentury. Available at: www.census.gov/newsroom/releases/archives/population/cb08-123.html. Accessed December 22, 2010.

[44] Lafortune G, Balestat G. Trends in severe disability among elderly people: assessing the evidence in 12 OECD countries and the future implications. OECD Health Working Papers, No. 26. OECD Publishing, 2007.

[45] Perruccio AV, Power JD, Badley EM. Revisiting arthritis prevalence projections—it's more than just the aging of the population. J Rheumatol 2006;33:1856–62.

[46] Braybrooke J, Ahn H, Gallant A, et al. The impact of surgical wait-time on patient-based outcomes in posterior lumbar spinal surgery. Eur Spine J 2007;16:1832–9.

[47] Barua B, Rovere M, Skinner BJ. Waiting your turn-wait-times for health care in Canada. Studies in Health Care Policy-Fraser Institute, 2010.

[48] Aiken AB, Harrison MM, Atkinson M, et al. Easing the burden for joint replacement wait-times: the role of the expanded practice physiotherapist. Healthc Q 2008;11:62–6.

[49] Mahon JL, Bourne RB, Rorabeck CH, et al. Health-related quality of life and mobility of patients awaiting elective total hip arthroplasty: a prospective study. CMAJ 2002;167:1115–21.

[50] Health Canada. First Ministers' Accord on Health Care Renewal. Available at: http://www.hc-sc.gc.ca/hcs-sss/delivery-prestation/fptcollab/2003accord/index-eng.php. Accessed September 28, 2011.

[51] Ontario Ministry of Health and Long-term Care. Provincial wait time trends. Available at: www.waittimes.net/SurgeryDI/EN/wt_trend.aspx?view=1. Accessed September 28, 2012.

[52] Porter ME. What is value in health care? N Engl J Med 2010;363:2477–81.

[53] Genevay S, Atlas SJ. Lumbar spinal stenosis. [review]. Best Pract Res Clin Rheumatol 2010;24:253–65.

[54] Battié MC, Jones CA, Schopflocher DP, Hu RW. Health-related quality of life and comorbidities associated with lumbar spinal stenosis. Spine J 2012;12:189–95.

[55] Malmivaara A, Slatis P, Heliovaara M, et al. Surgical or nonoperative treatment for lumbar spinal stenosis. Spine 2007;32:1–8.

[56] Amundsen T, Weber H, Nordal HJ, et al. Lumbar spinal stenosis: conservative or surgical management? A prospective 10-year study. Spine 2000;25:1424–35; discussion 1435–6.

[57] Mirza SK, Deyo RA. Systematic review of randomized trials comparing lumbar fusion surgery to nonoperative care for treatment of chronic back pain. Spine 2007;32:816–23.

[58] Chou R, Baisden J, Carragee EJ, et al. Surgery for low back pain: a review of the evidence for an American Pain Society Clinical Practice Guideline. Spine 2009;34:1094–109.

[59] Iguchi T, Kurihara A, Nakayama J, et al. Minimum 10-year outcome of decompressive laminectomy for degenerative lumbar spinal stenosis. Spine 2000;25:1754–9.

[60] Oertel MF, Ryang YM, Korinth MC, et al. Long-term results of microsurgical treatment of lumbar spinal stenosis by unilateral laminotomy for bilateral decompression. Neurosurgery 2006;59:1264–9; discussion 1269–70.

[61] Yamashita K, Ohzono K, Hiroshima K. Five-year outcomes of surgical treatment for degenerative lumbar spinal stenosis: a prospective observational study of symptom severity at standard intervals after surgery. Spine 2006;31:1484–90.

[62] Jönsson B, Annertz M, Sjöberg C, Strömqvist B. A prospective and consecutive study of surgically treated lumbar spinal stenosis. Part II: five-year follow-up by an independent observer. Spine 1997;22:2938–44.

[63] Atlas SJ, Keller RB, Wu YA, et al. Long-term outcomes of surgical and nonsurgical management of lumbar spinal stenosis: 8 to 10 year results from the maine lumbar spine study. Spine 2005;30:936–43.

[64] Cornefjord M, Byröd G, Brisby H, Rydevik B. A long-term (4- to 12-year) follow-up study of surgical treatment of lumbar spinal stenosis. Eur Spine J 2000;9:563–70.

[65] Cavuşoğlu H, Kaya RA, Türkmenoglu ON, et al. Midterm outcome after unilateral approach for bilateral decompression of lumbar spinal stenosis: 5-year prospective study. Eur Spine J 2007;16:2133–42.

[66] Hee HT, Wong HK. The long-term results of surgical treatment for spinal stenosis in the elderly. Singapore Med J 2003;44:175–80.

[67] Slätis P, Malmivaara A, Heliövaara M, et al. Long-term results of surgery for lumbar spinal stenosis: a randomised controlled trial. Eur Spine J 2011;20:1174–81.

[68] Nakanishi K, Tanaka N, Fujimoto Y, et al. Medium-term clinical results of microsurgical lumbar flavectomy that preserves facet joints in cases of lumbar degenerative spondylolisthesis: comparison of bilateral laminotomy with bilateral decompression by a unilateral approach. J Spinal Disord Tech 2013;26:351–8.

[69] Martin BI, Mirza SK, Comstock BA, et al. Reoperation rates following lumbar spine surgery and the influence of spinal fusion procedures. Spine 2007;32:382–7.

[70] Bruyère O, Ethgen O, Neuprez A, et al. Health-related quality of life after total knee or hip replacement for osteoarthritis: a 7-year prospective study. Arch Orthop Trauma Surg 2012;132:1583–7.

[71] Nilsdotter AK, Isaksson F. Patient relevant outcome 7 years after total hip replacement for OA—a prospective study. BMC Musculoskelet Disord 2010;11:47.

[72] Núñez M, Lozano L, Núñez E, et al. Total knee replacement and health-related quality of life: factors influencing long-term outcomes. Arthritis Rheum 2009;61:1062–9.

[73] Rat AC, Guillemin F, Osnowycz G, et al. Total hip or knee replacement for osteoarthritis: mid- and long-term quality of life. Arthritis Care Res (Hoboken) 2010;62:54–62.

[74] Cushnaghan J, Coggon D, Reading I, et al. Long-term outcome following total hip arthroplasty: a controlled longitudinal study. Arthritis Rheum 2007;57:1375–80.

[75] Cushnaghan J, Bennett J, Reading I, et al. Long-term outcome following total knee arthroplasty: a controlled longitudinal study. Ann Rheum Dis 2009;68:642–7.

[76] Corbett KL, Losina E, Nti AA, et al. Population-based rates of revision of primary total hip arthroplasty: a systematic review. PLoS One 2010;5:e13520.

[77] Gandhi R, Tsvetkov D, Davey JR, Mahomed NN. Survival and clinical function of cemented and uncemented prostheses in total knee replacement: a meta-analysis. J Bone Joint Surg Br 2009;91:889–95.

[78] Busija L, Osborne RH, Nilsdotter A, et al. Magnitude and meaningfulness of change in SF-36 scores in four types of orthopedic surgery. Health Qual Life Outcomes 2008;6:55.

[79] Slover J, Abdu WA, Hanscom B, Weinstein JN. The impact of comorbidities on the change in short-form 36 and oswestry scores following lumbar spine surgery. Spine 2006;31:1974–80.